HULU TERENGGANU HYDROELECTRIC PROJECT
VALUE ENGINEERING AND EMBEDDED PARTS ISSUE

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ABSTRACT

The exploration and development of the hydro potential in the Terengganu River Basin commenced in the late 1970's with the construction of the Kenyir Multi-purpose Dam Project or Terengganu Hydroelectric Project (400 MW) between 1979 and 1983. It was followed by the conduct of feasibility study and feasibility re-appraisal in mid 1980's and 1997 respectively for the Hulu Terengganu Hydroelectric Project which is located upstream of the Kenyir Lake. The construction of the Hulu Terengganu Hydroelectric Project was put out to tender in 2009.

The Hulu Terengganu Hydroelectric Project as per the original tender design comprises the Puah Power Scheme (250 MW) and Tembat Water Transfer Scheme. The Tembat Water Transfer Scheme is designed to solely divert the Tembat River water into the Puah Scheme catchment without power generation facilities.

In April 2010, a project consultant was engaged by Tenaga Nasional Berhad (TNB, Project Owner) to act as the Owner's Engineer and to undertake tender design review, detailed engineering design and construction supervision of the Hulu Terengganu Hydroelectric Project. The recommendation for the development of the Tembat Power Scheme is highlighted among others in the Re-assessment Study of the Tembat Transfer Scheme Report [SNCL, KTA & G&P, 2011]. The approval to proceed with the conversion of the Tembat Water Transfer Scheme into the Tembat Power Scheme (15 MW) was given in early 2012.

The construction of the Hulu Terengganu Project was commenced in 2011, the two generating units of the Puah Power Scheme have been put into commercial operation since December 2015 and the Tembat Power Scheme is presently targeted for completion by the end of 2016.

This paper gives a brief description of the Hulu Terengganu Project and some of the value engineering works executed at the stages of tender design review, detailed engineering design and construction supervision of the Project. The value engineering works have enhanced the Project benefits which include increment in generation capacity & annual energy output (MW & Gwh/annum) and reduction in cost & time of construction. A brief description of the embedded parts issue relating to the costs for transportation and installation of the parts is also given. The issue has been resolved in accordance with the Sub-Clause 3.5 Determination in the Contract.

KEYWORDS - ***water, generation, value, issue***

1. Introduction

The Hulu Terengganu Hydroelectric Project is located at upstream of the Kenyir Reservoir in the Terengganu state of Malaysia. Kenyir Reservoir is created as a result of the construction of the 400 MW Terengganu (Kenyir) Hydroelectric Project in the 1980's. The location map of the Hulu Terengganu Project is shown on Figure 1.

The currently constructed Hulu Terengganu Hydroelectric Project has a total installed capacity of 265 MW and consists of two hydro power schemes namely Puah Power Scheme (2x125 MW) and Tembat Power Scheme (2x7.5 MW). The Puah Power Scheme has a catchment area of 511 km^2 including 101 km^2 of the Tembat catchment. The annual average energy output of the Hulu Terengganu Hydroelectric Project has been estimated to be 467 GWh/annum, of which 413 GWh/annum are produced from the Puah generating units and 54 GWh/annum from the Tembat generating units.

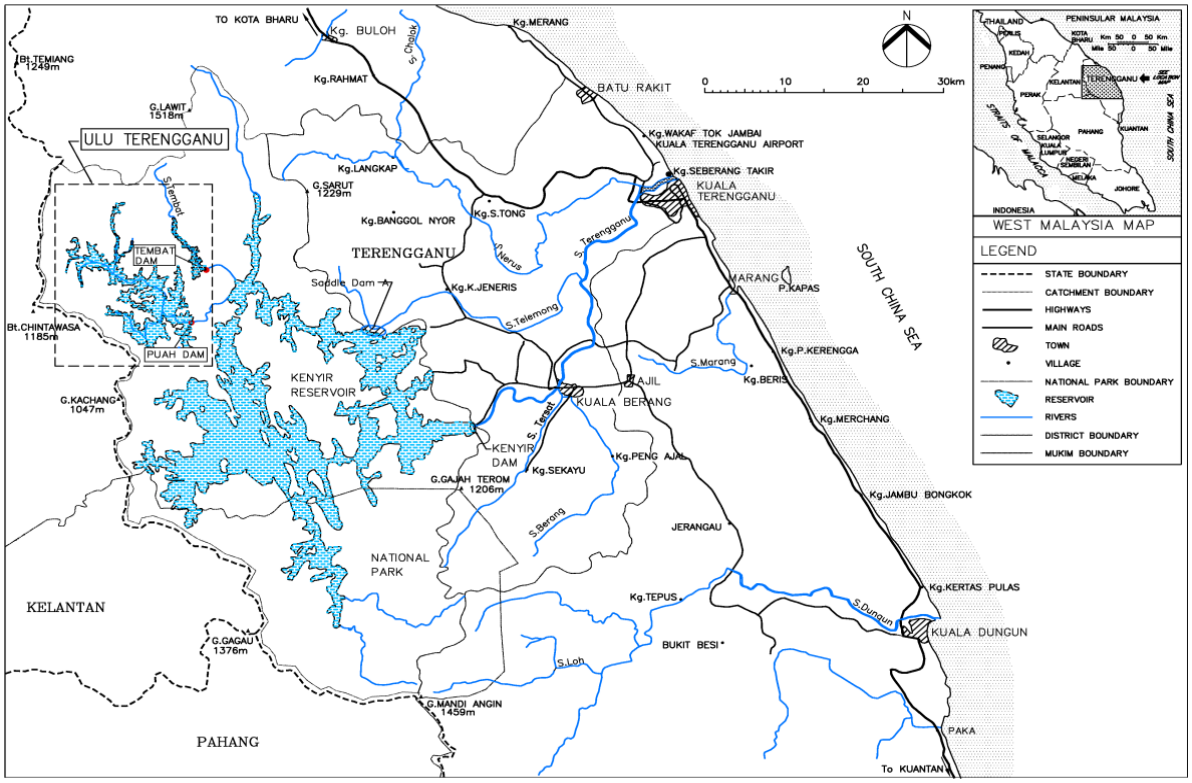

Figure 1: Location Map of Hulu Terengganu Hydroelectric Project

The construction of the Hulu Terengganu Hydroelectric Project is executed via the following six (6) contract packages:-

- Lot CW1 – Preliminary Works
- Lot CW2 – Main Civil Works and Associated Works
- Lot CW3 – Tembat Civil Works and Associated Works
- Lot EM1 – Electrical and Mechanical Works
- Lot EM2 – 275 kV Switchyard and Transmission Lines Works
- Lot EM3 – Electrical and Mechanical Works of Tembat Generating Units

Lot CW3 and Lot EM3 are contract packages specifically prepared/awarded for the Tembat Power Scheme which is a conversion from the Tembat Water Transfer Scheme.

2. Project Features

The main features of the Puah Power Scheme comprise a 79 m high earthfill dam, a gated spillway with 3 radial gates, two headrace tunnels & tailrace tunnels, a surge chamber, an emergency cable ventilation tunnel, an access tunnel, a tailrace tunnel, an intake structure, an underground powerhouse & other appurtenant structures and a 275 kV switchyard.

The Puah reservoir at the El. 296 m full supply level (FSL) will have a surface area for about 70 km^2 and a gross storage of about $1{,}735.0 \times 10^6$ m^3.

The principle features of the Tembat Power Scheme are a 36 m high concrete dam with a free overflow spillway, a headrace tunnel, an intake structure, a surface power house and other appurtenant structures.

The Tembat reservoir at the El. 430 m FSL will have a surface area of 2.2 km^2 and a gross storage of about 19.90×10^6 m^3.

Figure 2 shows the general layout of the Hulu Terengganu Hydroelectric Project and access road.

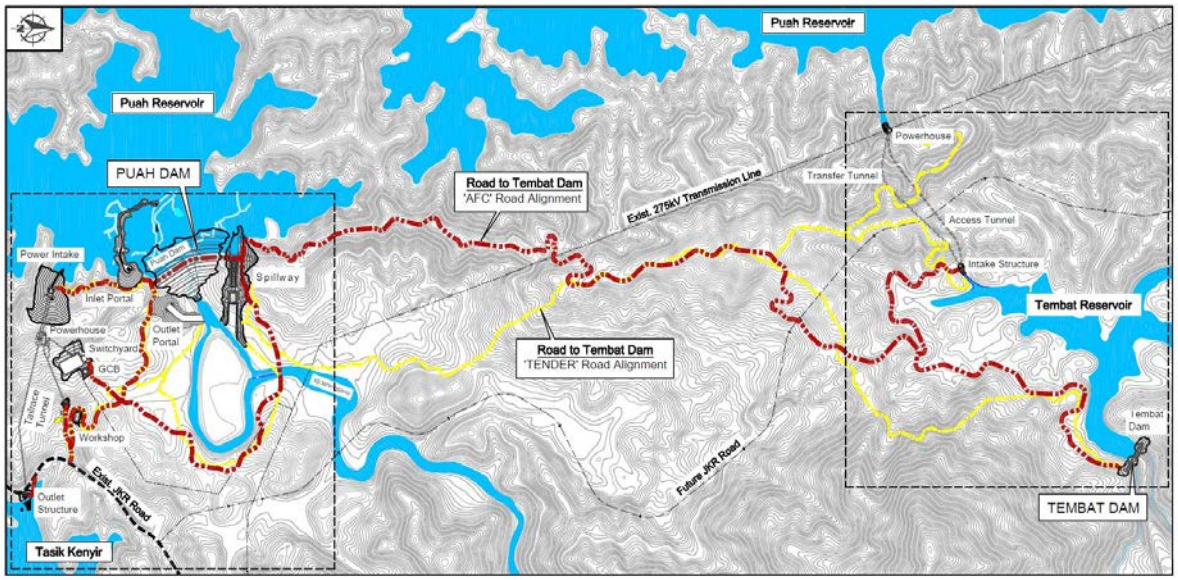

Figure 2: General Layout of Hulu Terengganu Hydroelectric Project

3. Environmental Aspect

The surface area of the Puah Reservoir and that of the Tembat Reservoir are about 19% and 0.6% respectively of the surface area of the existing Kenyir Reservoir (370 km^2 at El. 145m FSL). Some data (at full supply level FSL) of the three reservoirs are shown below.

Reservoir	Puah	Tembat	Kenyir
• Gross Storage (million cu. m.)	1,735	19.9	13,600
• Live Storage (million cu. m.)	1,085	5.95	7,400
• Surface Area (sq. km.)	70	2.2	369

Environmental impact due to the construction of the Hulu Terengganu Hydroelectric Project has been assessed to be comparatively not major in significance. Conditional approval of the Detailed Environmental Impact Assessment (DEIA) was obtained from the Department of Environment (DOE) in March 2009. The conditions of the DOE's approval include among others the preparation and submission of the following document and reports.

- Environmental Management Plan (EMP)
- Quarterly progress report to monitor compliance with DEIA approval conditions
- Quarterly monitoring reports for water quality, air quality, noise and vibration
- Annual environmental audit report (from a DOE registered environmental consultant)

Mitigation measures have been taken during the construction of the Hulu Terengganu Project to address the following environmental issues highlighted in the EMP.

- Reduction in low flow affecting downstream beneficial uses during the operation phase
- Soil erosion due to logging activities and construction activities
- Rescue/relocation of affected wildlife due to construction and reservoir impoundment
- River water quality during construction period
- Air and noise pollution during construction period
- Vibration caused by blasting and reservoir induced seismicity

The Hulu Terengganu Project was given approval of Development Order in September 2009 by Hulu Terengganu District Council, the local authority. Development Order is a statutory requirement prior to construction and the application for Development Order includes among others submission of a Erosion and Sediment Control Plan to the local authority for approval.

4. Value Engineering Works

The objective of implementation of Value Engineering is understood to improve value of products and services via systematic application of methods or techniques and examination of functions so as to provide the needed functions at the lowest overall cost. Value (as defined in Wikipedia) is the ratio of function to cost and can therefore be increased by either improving the function or reducing the cost.

Value engineering practices have been implemented at the start of performing the engineering services in the stage of tender review, through the detailed engineering phase and all the way to the end of construction for the Hulu Terengganu Project. Value engineering performed in the following works among others has shown to provide enhancement in the project benefits. It involved identifying (hence avoiding) unnecessary cost and optimizing design, construction and future operation & maintenance (hence to reduce cost and time).

4.1 Tembat Dam

According to the tender design drawings, the Tembat concrete dam would have a gated spillway with three (3) radial gates each of 14m x 10m (h x w) in dimension and the full supply level (FSL) is El. 423.0 m. The Tender Design Review Report [SNCL Power, 2010] recommends an ungated overflow spillway with 60m long spillway crest at El. 429.0m, the original FSL of El. 423.0m is retained.

Figure 3 shows the overflow section of the original gated spillway (tender drawing) and that of the final ungated spillway (AFC drawing) for the Tembat Dam.

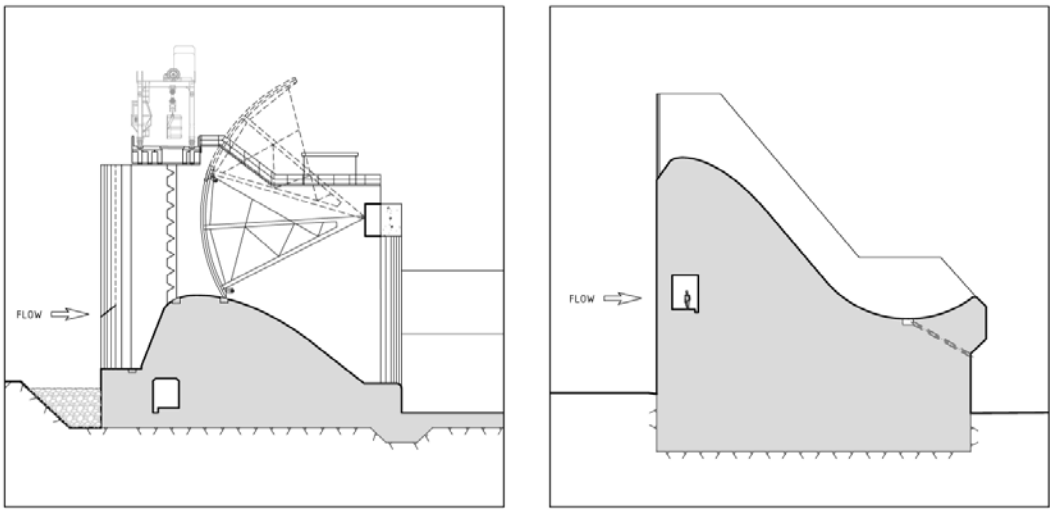

Figure 3: Tembat Dam Section - Gated & Ungated Spillway

The design change to the Tembat Dam spillway from the gated spillway to the ungated spillway resulted in deletion of some thirty (30) work items in the Bill of Quantities and reduction of about RM 9.70 x 10^6 in the cost (i.e. total costs of the related work items allowed in BOQ) as shown below.

Work Item (Tembat Gated Spillway)	RM (10^6)
• Anchorages radial gates & trunion support for spillway	0.20
• Spillway gate stoplogs assembly	1.05
• Spillway radial gates assembly	5.91
• Stoplog gantry crane assembly	1.00
• Maintenance equipment, tools & appliances for spillway gates	0.34
• Supply, install, test & commission 110V DC batteries and battery charges	0.28
• Supply, install, test & commission power and control cables	0.15
• Gate seals	0.11
• Supply, install, test & commission 415V switchboard at spillway	0.16
• Others	0.50

Figure 4 shows the elevation view of the Tembat dam

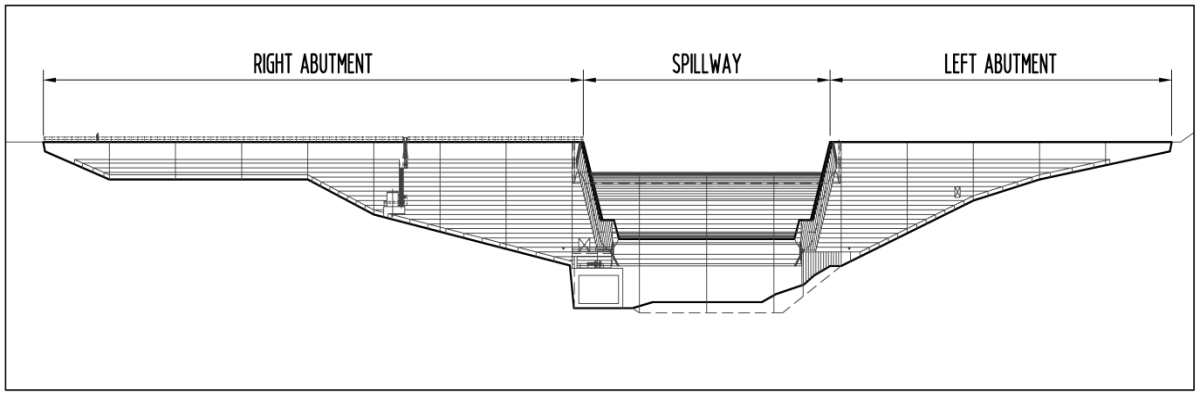

Figure 4: Elevation View of Tembat Dam

4.2 Tembat Generation Facilities

The Tembat water transfer scheme was studied during the feasibility study in the early 1980's and the feasibility re-appraisal in mid 1990's. The findings of these studies are contained in the Feasibility Study Report [SMEC, 1983] and the Re-appraisal Report [SMEC, 1997]. The scheme is shown then to be designed for diversion or transfer of the Tembat water to the Puah catchment alone without generation facility.

Proposal for the Tembat water transfer works to be designed with generation facility is however contained in the Tender Design Review Report [SLPM, 2010]. A feasibility study of the Tembat Hydroelectric Project and a re-assessment study of the Tembat Transfer Scheme were respectively done in May and July 2011. The Feasibility Study Report [SNCL, KTA & G&P, 2011] concludes among others the Tembat Power Scheme (2x8 MW) to be a viable development, and the economic viability of the Tembat Power Scheme (16 MW) has been re-confirmed in the Re-assessment Report [SNCL, KTA & G&P, 2011].

Subsequent to the approval of TNB to proceed with the conversion of Tembat water transfer scheme to Tembat power scheme of 15MW installed capacity, two additional contract packages were prepared and awarded for the construction of the civil works (Lot CW3) and the electrical & mechanical works (Lot EM3) of the Tembat Power Scheme. The Lot CW3 does not include the Tembat Dam and the access road from Puah to Tembat Dam which are part of the works in Lot CW2. The accepted Contract Price of Lot CW3 is about RM124.2 × 10^6 and that of Lot EM3 is US$4.4 × 10^6 & RM 13.19 × 10^6.

Figure 5 shows the layout of the Tembat Power Scheme and the original Tembat Transfer Scheme (Tender design). Figure 6 shows the longitudinal section of the Tembat Power Scheme.

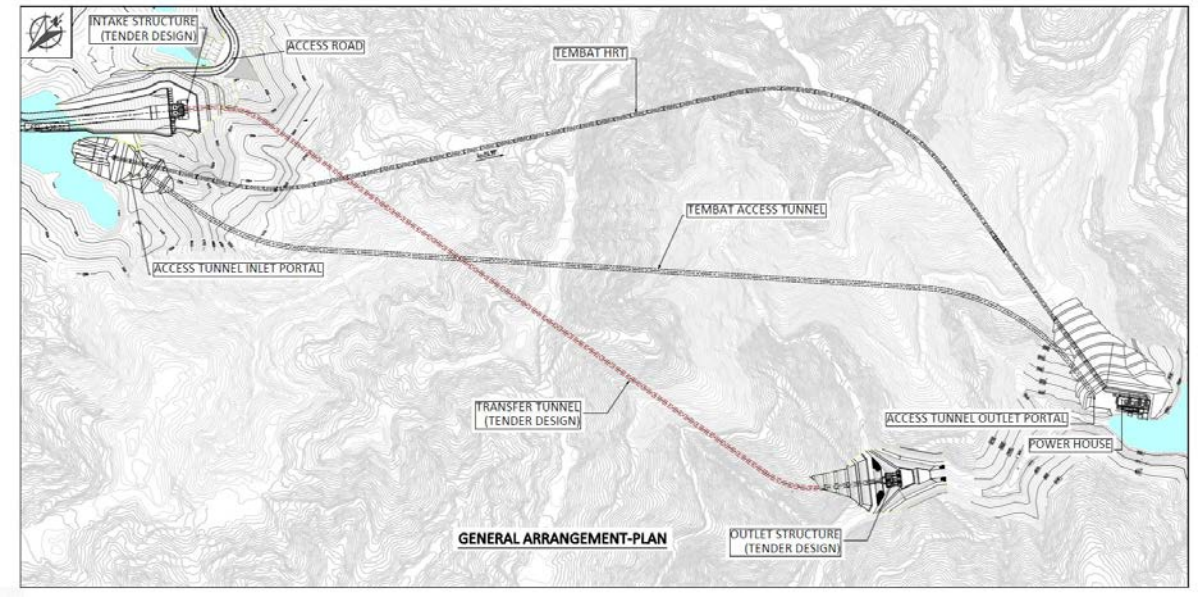

Figure 5: Layout of Tembat Power Scheme & Water Transfer Scheme

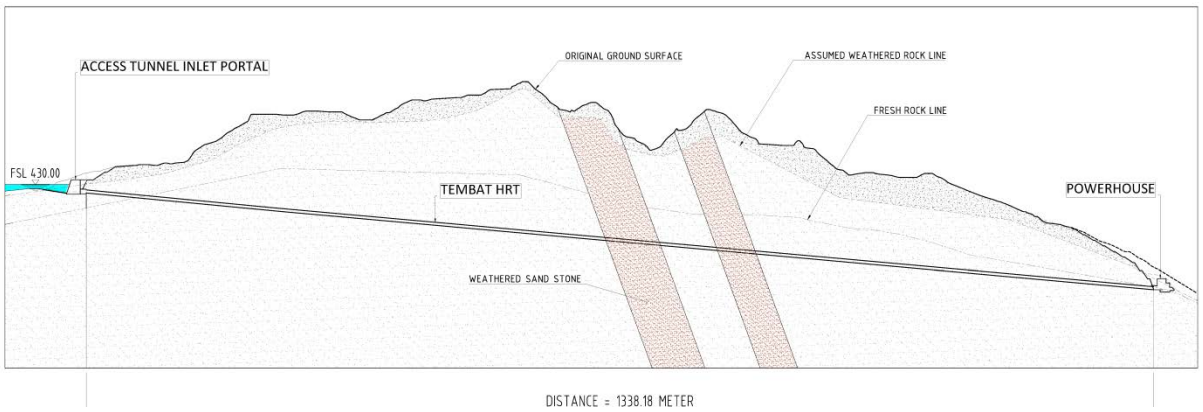

Figure 6: Longitudinal Section of Tembat Power Scheme

The Tembat Power Scheme provides additional generation benefits of 15 MW in capacity and 54 GWh/annum in annual average energy output for the Hulu Terengganu Hydroelectric Project. The Tembat Power Scheme has been found to be economically viable based on the generation benefits and incremental costs.

4.3 Access Road to Tembat Dam

The originally designed route of the permanent access from the Puah site to the Tembat Dam was realigned during detailed design. The new route has reduced culvert construction and earthworks (i.e. cut and fill) as well as steep road gradient.

The original (Tender drawings) and final route (AFC drawings) for the access road to the Tembat is shown in Figure 1.

A summary of the breakdown of the estimated costs for the construction of the access road to Tembat Dam using BQ unit rates and basing on Tender drawing and AFC drawing is shown below.

Description	Tender Drawing	AFC drawing
	Estimated Amount (RM)	Estimated Amount (RM)
Surface Excavation and Earthworks	22,674,864.19	10,440,673.34
Protection and Support of Surface Excavation	5,354,421.50	2,539,197.57
Drainage Work	6,900,881,89	10,191,402.59
Road Construction	3,246,260.55	3,739,668.92
Concrete Production & Construction	382,878.24	
Concrete in Structure	555,380.82	
Total	**39,084,687.19**	**26,910,942.42**

The new alignment of route for the access road to Tembat Dam is about RM 12.0 million less in construction cost than the original route shown on tender drawings.

4.4 Design Changes to Power Cavern

A number of design changes were made to the concepts inherent in the tender drawings for the Puah underground power. Some of these design changes are summarised below.

a) Changes in draft tube pit and spiral case area

The deep dewatering and drainage sump was eliminated avoiding excavation of a deep narrow slot. It was replaced by a dewatering sump in the surge cavern without increasing surge chamber excavation.

The shallow power station drainage sump located between the units is in an excavated area for the draft tube pits which is 6.5 m below adjacent rock excavation as compared to 10.3 m shown on the tender drawing.

The above changes have resulted in reduction of estimated 1,300.0 m^3 in rock excavation (mostly around the spiral cases) and concrete volume.

b) Changes in cross section of draft tube tunnel

The width of excavation was reduced and the raw water intake configuration was modified to have the shape of the draft tube hydraulic outline as proposed by EM1, which requires less excavation. The temporary rock roof arch configuration was modified to minimize concrete above soffit.

The above changes have resulted in reduction of estimated 1,532.0 m^3 in rock excavation and concrete volume.

c) Elimination of horizontal notch for ventilation duct

Excavation of a 70 m long notch 2.0 m × 2.5 m in size to form a horizontal slot in downstream wall of power cavern (shown on the tender drawing for ventilation duct) was eliminated to ensure structural safety, and ducting was provided inside the cavern section instead.

The above change has leaded to elimination of about 630 m^3 of rock excavation and also saving in about 270 m^3 of concrete that would have been required around the ventilation duct.

d) Elimination of crane beam notches at crane runway level

Crane beam anchorage to cavern wall (shown on tender drawings) as support for the main EOT power station 300 t crane was eliminated, concrete columns down to rock (at El. 127 m, 135 m and 147 m) were constructed to support the crane. The columns were bolted to the rock (where necessary) to increase load capacity for the 800 mm square section of columns shown on the tender drawings.

The above change has resulted in removal of requirement for anchors and saving of RM849,301.0 the cost allowed in the BOQ for crane beam anchorage.

e) Change in surge cavern excavation

Change was made to reduce excavation area between draft tube gate exit and the tailrace tunnel entry transition. The hydraulic transition in the region was then optimised to provide as close as possible a linear increase in flow velocity for hydraulic efficiency.

The above change has resulted in reduction of estimated 2,355.0 m^3 in rock excavation and 1,167.0 m^3 concrete volumes.

f) Elimination of suspended floor slab at El. 156.5 m.

The concrete surge chamber maintenance deck (shown on tender drawing) was eliminated except for the 5.8 m wide deck across the top of draft tube gate piers and the concrete slab on rock surface.

The above change resulted in saving of estimated 165 m^3 in concrete volume.

There are few more other design changes which have resulted in less volume of rock excavation. Nevertheless, the Employer/TNB is not benefitted from the saving in rock excavation cost except the construction time as the power cavern excavation is a lump sum price.

A summary of estimated saving in cost due to the above design changes to power cavern is shown below.

Item	Estimated Cost Saving (RM)	Remark
a)	903,123.00	Concrete
b)	1,134,752.00	Concrete
c)	187,572.00	Concrete
d)	849,301.00	Anchors
e)	864,397.00	Concrete
f)	122,216.00	Concrete
	4,061,361.00	

(Source: SNCL, KTA and G&P, 2012)

5. Embedded Parts Issue

The issue is related to the costs for transportation and installation of Pier Nose steel lining and Stainless Steel Pipes which are "embedded parts supplied by others" under Main Civil Works (Lot CW2) contract package.

The contractor disagreed with the Chief Resident Engineer's assessment basing on contract unit rates and requested for an Engineer's Determination in accordance with the contract provisions.

5.1 Contract Provisions

Sub-Clause 3.5 of GCC

Whenever these Conditions provide that the Engineer shall proceed in accordance with this Sub-Clause 3.5 to agree or determine any matter, the Engineer shall consult with each Party in an endeavour to reach agreement. If agreement is not achieved, the Engineer shall make a fair determination in accordance with the Contract, taking due regards of all relevant circumstances.

The Engineer shall give notice to both Parties of each agreement or determination, with supporting particulars. Each Party shall give effect to each agreement or determination unless and until revised under Clause 20 [Claims, Disputes and Arbitration].

Sub-Clause 12.3 (a) of GCC

For each item of work, the appropriate rate or price for the item shall be the rate or price specified for such item in the Contract or, if there is no such item, specified for similar work. However, a new rate or price shall be appropriate for an item of work if:

i). the measured quantity of the item is changed by more than 10% from the quantity of this item in the Bill of Quantities or other Schedule,
ii). this change in quantity multiplied by such specified rate for this item exceeds 0.01% of the Accepted Contract Amount,
iii). this change in quantity directly changes the Cost per unit quantity of this item by more than 1%, and
iv). this item is not specified in the Contract as a "fixed rate item".

Particular Condition for Adjustment to Rate

A new rate is only applicable for an item of work in the Bill of Quantities if:

a) the change in quantity of the Bill of Quantities item between original estimated and finally measured quantities, when multiplied by the specified rate, exceeds 0.1% of the Accepted Contract Amount; and
b) either Party submits a request to the Engineer to vary such rate together with a full justification and proposal for the unit adjustment. After due consultation with the Parties, the Engineer shall after examining the justification submitted, determine if a new rate is appropriate and reasonable.

The above shall take precedence over provisions under sub clause 12.3(a) (i), (ii) and (iii) of the Conditions of Contract.

Note: The Particular Condition for Adjustment to Rate was included at the post tender and pre-award stage.

Bill of Quantity

BQ Item No. 17-18 the installation of miscellaneous embedded metalwork supplied by others

Quantity = 8,500 kg, Unit rate = RM 6.88

BQ Item No. 21-28 lifting, storage and transport of embedded parts to point of assembly

Quantity = 5 ton, Unit rate = RM 152.10

BQ Item No. 21-30 Welding of stainless steel components for embedded parts including weld materials

Quantity = 20 kg. Unit rate = RM 41.06

5.2 Engineer's Assessment/Determination

There are appropriate rates for the transportation and installation of the "Pier Nose" and "Stainless Steel Pipe" which are "embedded parts" specified in the Contract (Lot CW2).

- Measured quantity of Pier Nose = 12.6 ton
- Measured quantity of Stainless Steel Pipes = 58.42 ton
- Measured quantity of welding of stainless steel components = 158.16 kg.

In accordance with CC Sub-Clause 12.3 (a), the Contractor would have been entitled to request for new appropriate rates for the above said work items. However the Contractor's request does not qualify applicability of the Particular Condition for Adjustment to Rate, unless TNB consents to relax the restrictions on applicability of this new Adjustment to Rate provisions.

Consultations

In the process of consultation, the Contractor reduced their claim amount and requested to amicably resolve the Pier Nose and Stainless Steel Pipe issues for RM 148,940.00 (at equivalent rate of RM 11.82/kg) and RM 582,552.33 (at equivalent rate of RM 9,971.80/ton) respectively. These costs are deemed to cover all costs for transportation and installation of the Pier Nose steel lining and Stainless Steel Pipes (including welding and pressure testing).

Engineer's View

The Contractor's above request is not entirely unreasonable by taking into consideration for the following

- Each of the two pier nose piece is big 2.5m × 1.9m × 0.8m (L×W×H) and heavy 6.3 ton. The pier nose was to be transported to draft tube tunnel via tailrace tunnel (instead of main access tunnel) with 200 t lorry and unloaded by means of 45 t mobile crane.
- Lack of stainless steel pipe details in tender drawings to possibly enable estimation of stainless steel quantity.
- Constraint of work space.
- Temporary lifting device and chain block are to be used for stainless steel pipe installation due to omission of temporary overhead crane as a result of not to stop power house cavern excavation for crane beam construction but to excavate power house cavern from top to bottom for avoidance of delay to power house cavern excavation.

Client's Response

The TNB Project Management agreed to the Engineer's above views and accepted the Contractor's cost claim of RM 142,940.00 (@RM 11.82/kg) for the transportation and installation of the Pier Nose and RM 582,552.33 (@ RM 9,971.80/ton) for that of the Stainless Steel Pipes.

6. Concluding Remark

a) The Hulu Terengganu Hydroelectric Project will annually generate about 470 GWh of green and renewable energy from the two Puah and Tembat Power Station.

b) Value engineering has been performed throughout the tender design, detailed engineering design and construction periods of the Hulu Terengganu Project. The several value engineering works (described in Section 4 above) are shown to provide the generation enhancement or/and the reduction in cost/time of construction for the Hulu Terengganu Project.

- The development of the Tembat Water Transfer Scheme with power generation facilities has increased the value of the Tembat Water Transfer Scheme and establishes a more worth for the water transfer function. It provides additional generating capacity of 15 MW and annual average energy output of 54 GWh/annum for the Hulu Terengganu Hydroelectric Project.
- The design change in the Tembat Dam Spillway from "gated" to "free overflow or ungated" provides the needed function of a spillway with a saving in cost for the spillway construction.
- The adoption of the new route for the access road to the Tembat Dam provides the alternative for Tembat Dam Road at a lower cost than the one shown in tender design.
- The changes made to some of the design concepts in the tender drawings for the Puah power station/cavern have enabled avoidance of some unnecessary costs

c) The consultation with each party in the Engineer's Determination process is shown to be fruitful in achieving agreement (from the parties) on the costs for transportation and installation of the Pier Nose and the Stainless Steel Pipes. This embedded parts issue is resolved without brought under Clause 20 [Claim, Disputes and Arbitration] upon each party giving effect to the Determination.

7. Acknowledgement

The authors would like to thank the Management of Tenaga Nasional Berhad (TNB) for the permission to publish this paper. Any opinions expressed in the paper are the authors and do not necessarily reflect those of the TNB Management. The authors are entirely responsible for any shortcomings in the paper

References

1. Asia pacific Environmental Consultants Sdn Bhd "Hulu Terengganu Hydroelectric Project, Environmental Management Plan", June 2009
2. FIDIC, "Conditions of Contract for Construction, For Building and Engineering Works Designed By The Employer", 1999 Edition.
3. SNC-Lavalin, KTA Tenaga Sdn. Bhd., and G&P Professional Sd. Bhd., "Tembat Hydroelectric Project Feasibility Study Report", May 2011.
4. SNC-Lavalin, KTA Tenaga Sdn. Bhd. and G&P Professional Sdn. Bhd., " Re-assessment Study of the Tembat Transfer Scheme Report", July 2011.
5. SNC-Lavalin, KTA Tenaga Sdn. Bhd. and G&P Professional Sdn. Bhd., "Hulu Terengganu Hydroelectric Project, Design Optimization/Changes to Underground Power Cavern", 2012
6. SNC-Lavalin, "Value Engineering Procedure – Document Number 3501 – E", 2013.
7. Snowy Mountain's Engineering Corporation, "Hulu Terengganu Hydroelectric Project, Feasibility Study Report", November 1983
8. Snowy Mountain's Engineering Corporation, "Hulu Terengganu Hydroelectric Project, Re-Appraisal of Feasibility Study Report", November 1983
9. Tenaga Nasional Berhad, "Hulu Terengganu Hydroelectric Project, Lot CW2 – Main Civil and Associated Works", Contract Document, December 2010.

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